

Stellar Wobble by a Planet in a Disk

Limitation on Planet Detection by Astrometry

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Summary

- We consider the possibility of planet detection by astrometry.
- SIM has enough accuracy ($1\mu\text{as}$) to detect infant planets at star forming regions.
- Light from a circumstellar disk shifts the photo-center of the star-disk system, and may interfere with the astrometry to measure precise stellar positions.
- The disk light causes a photo-center shift as large as the amplitude of the dynamical stellar wobble by a Jupiter mass planet.
- However, SIM is not sensitive to extended disk's light, so the disk's contamination to the astrometry shift is less than $1\mu\text{as}$.

1. SIM: Space Interferometry Mission

Launch: 2009

Baseline: 10 m

Telescopes: 33 cm

Relative Accuracy:
 $1\mu\text{as}$



2. Stellar Wobble by a Planet

Astrometry shift by a Jupiter mass planet

36 μ as at 140 pc > 1 μ as of the SIM accuracy

Search for infant planets is possible

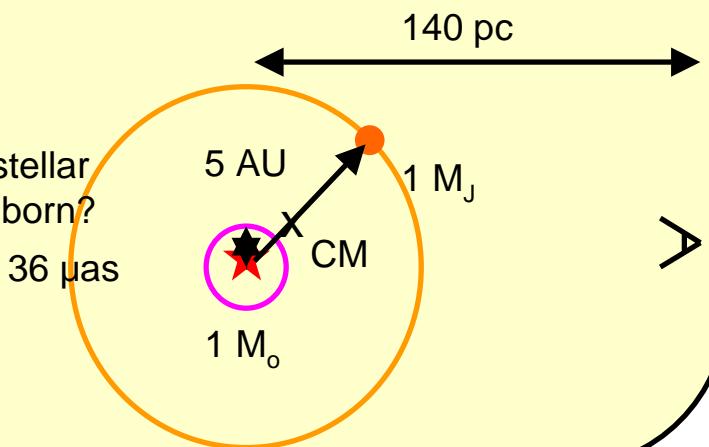
Taurus-Auriga molecular clouds

~200 T Tauri stars (Kenyon & Hartmann 1995)

D=140 pc

$10^5 - 10^7$ yr

At which epoch in young stellar evolution are planets born?



3. Disk's Contamination

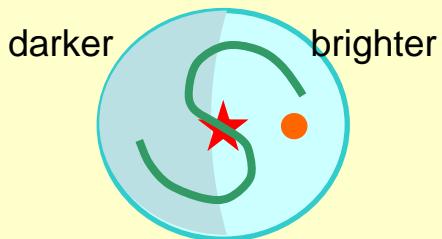
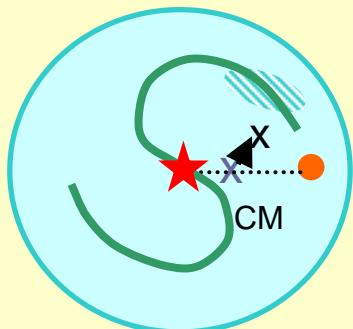
Dynamically

Shift of the mass-center

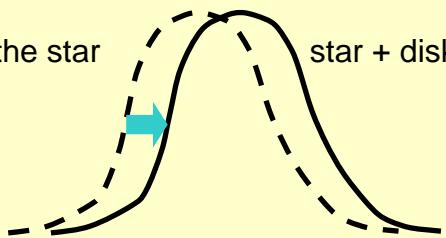
Optically

Shift of the photo-center

beam size >> disk's diameter



PSF of the star



4. Density Wave Pattern

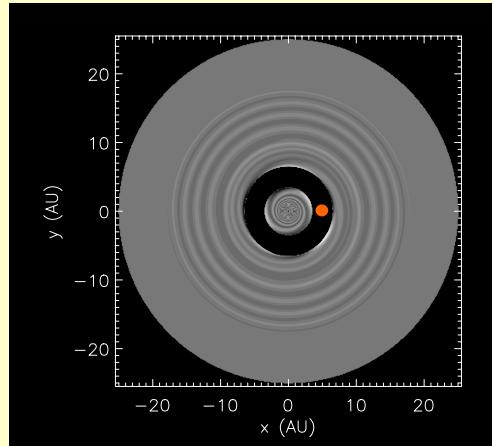
Linear calculation

2-D disks

A gap in the disk $[0.6r_p - 1.4r_p]$

$1-10 M_J$

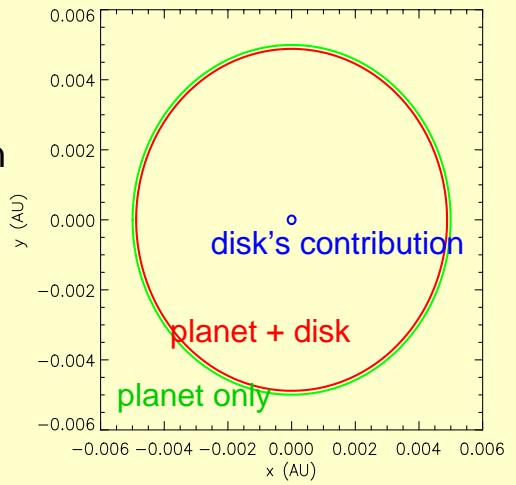
Circular and co-planer orbits



surface density

5. Dynamical Shift

Disk's dynamical effect is negligible even for a massive ($0.16 M_0$) disk



Motion of the stellar position

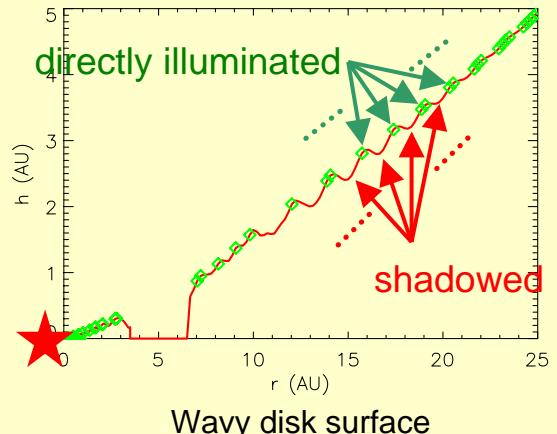
6. Optical Shift

Hydrostatic equilibrium in the z-direction

$$h = \sqrt{2\eta} / \Omega$$

Images of the disk's scattered light

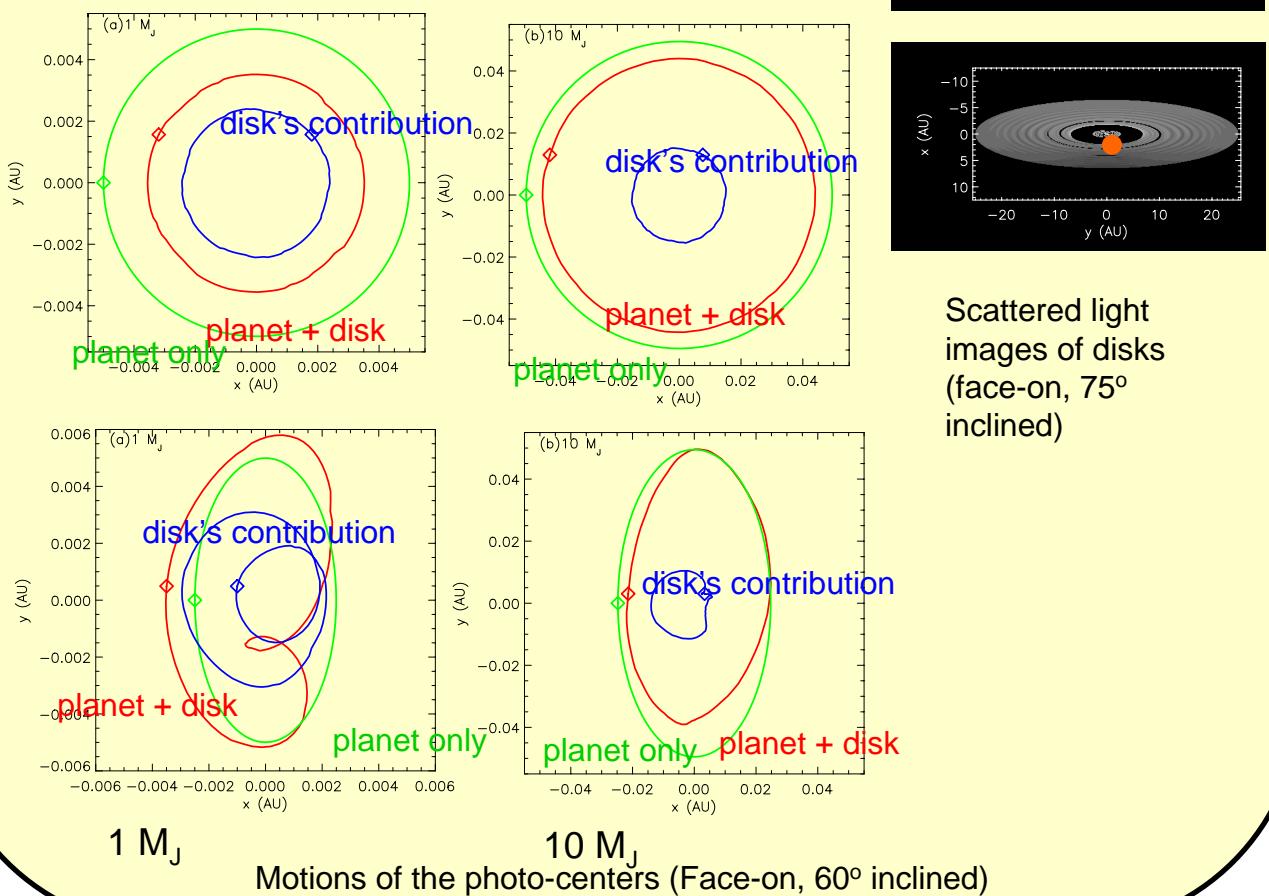
- At optical wavelengths (400-900 nm)
- Disk surface is modeled as being solid
- Totally scattered starlight at the surface
- Illuminating and shadowing the surface



Wobble of the photo-center

Disk contamination is not significant if

$$M > 10 M_J$$

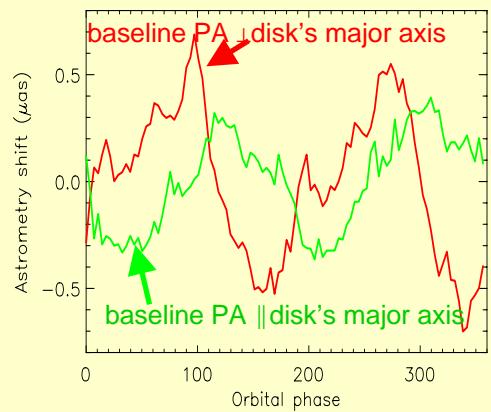


7. SIM Astrometry

SIM astrometry is not sensitive to extended sources larger than the fringe size,

$$\frac{\lambda = 0.5 \mu\text{m}}{b = 10 \text{m}} \approx 20 \mu\text{as} \approx 3 \text{ AU}$$

Disk contamination to the astrometry shift is less than $1 \mu\text{as}$ for a $1 M_J$ planet.



Disk's contamination to the SIM astrometry shifts